ASTROEDU

Peer-reviewed Astronomy Education Activities

The Sun in our box

Comparing the size of the Sun and the Earth building and using a pinhole camera.

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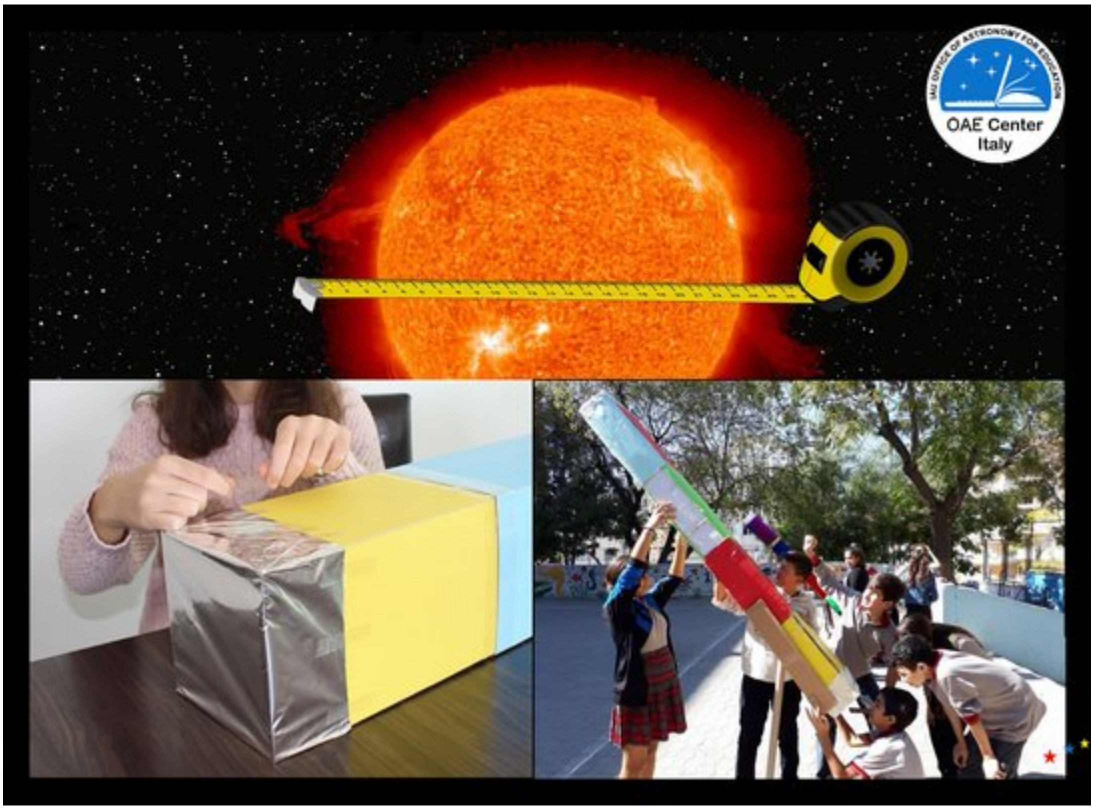


KEYWORDS

pinhole camera, light, experiment, dimension, earth, scale, hands-on, sun

CATEGORY

<QuerySet [<SciCategory: Mathematics>, <SciCategory: Physics>, <SciCategory: The Sun>]>

LOCATION

Outdoors

AGE

10 - 14

LEVEL

<QuerySet [<Level: Middle School>]>

TIME

3h

GROUP

Group

COST

Low Cost

SKILLS

<QuerySet [<Skills: Developing and using models>, <Skills: Engaging in argument from evidence>, <Skills: Using mathematics and computational thinking>]>

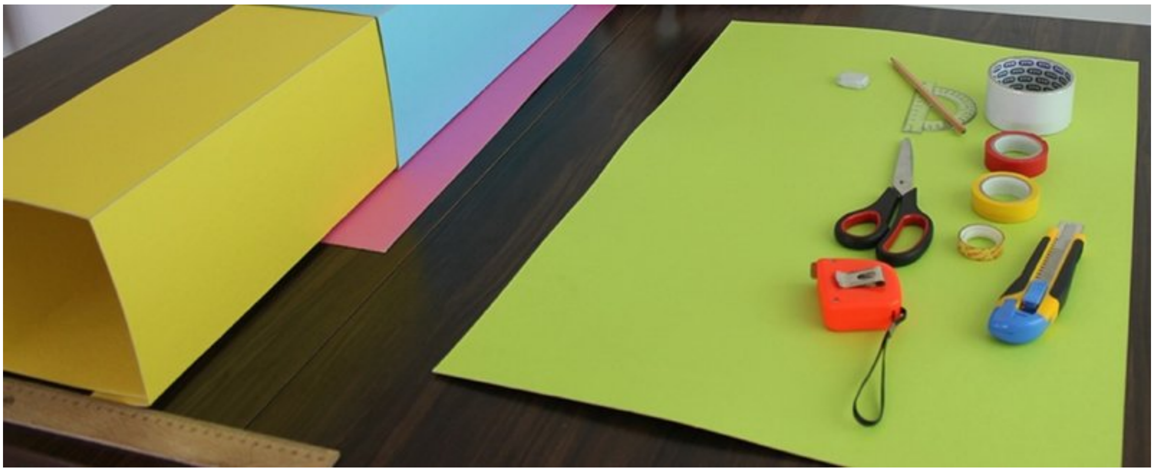
TYPE OF LEARNING

<QuerySet [<Learning: Discussion Groups>, <Learning: Observation based>, <Learning: Project-based learning>, <Learning: Structured-inquiry learning>]>

MATERIALS

For this activity, you will need:

- 3-4 layers of (colored) cardboard 45 X 65 cm
- aluminum foil or cardboard
- baking sheet (Wax paper)
- ruler, meter
- pin/needle
- pen, tape
- Scissors and (for older kids) utility knife
- A4 paper



GOALS

- Spark interest for astronomy and astronomical instrumentation
- Observe the behaviour of light, how the image of a light source is created through an objective and it can be used to create photographic images
- Grasp the basics of how scientific, statistical measurements are performeded.

LEARNING OBJECTIVES

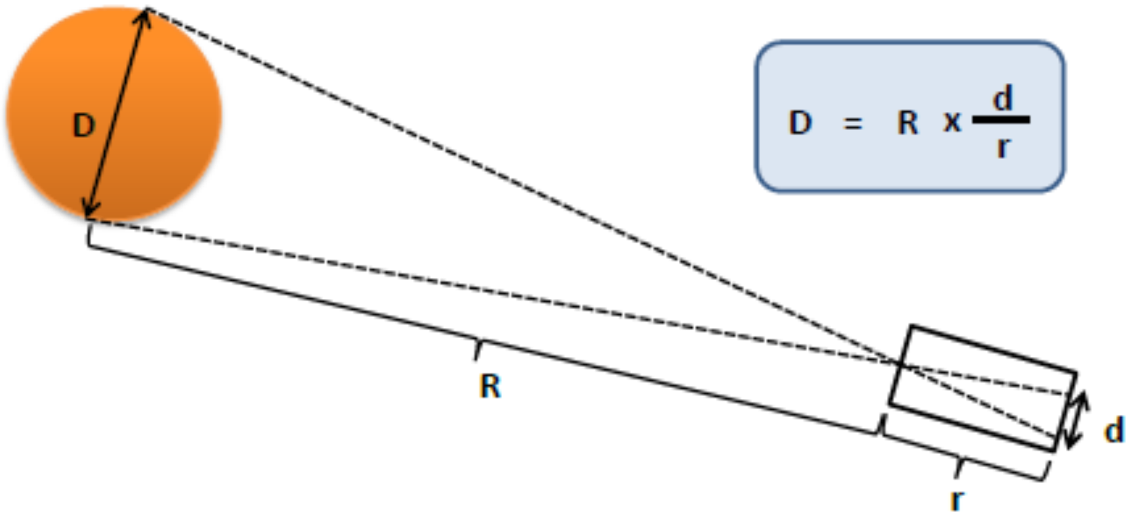
- Measure the size of the Sun and compare it with the size of the Earth
- Build and use a pinhole camera understanding the basics of how it works
- Learn how to compute proportions and use similar triangles to estimate sizes
- Learn how to perform a statistical measurement by using histograms and averages
- Learn the meaning of statistical errors and outliers

BACKGROUND

In this activity we will build and use a pinhole camera to project images from the Sun and to determine the diameter of this source. How does a pinhole camera work? The image of the light passing through the hole falls on the projection paper at the other end of the pinhole camera box. Using the image of the Sun formed here, we can infer the true diameter of the Sun.

To know more about Pinhole Camera follow this link.

The proportion used to calculate the dimension of the Sun originates from the similar triangles method.



where
D= Diameter of the Sun (to be calculated),
R= Distance from the Sun (provided),
d= Diameter of the Sun's Image (to be measured),
r= Distance of Pinhole to Screen paper (to be defined when building the pinhole camera).

Knowing the real distance between the Sun and the Earth (R= 149580000 km) we will be able to determine the Diameter fot he Sun, that is **D=1392700 km**.

Knowing that the diameter of Earth is E=12.742 km means **that D=109 E, meaning that the Sun has a diameter that is 109 times bigger than Earth!**

Notice that, even if the Sun is that much bigger than the Earth, it looks relatively small in the sky because of its huge distance. And that's also why the Moon, which is much smaller than the Sun, but even much closer, has the same apparent angular size as the Sun in the sky. By the way, the two objects having the same angular sizes in the sky are only a lucky chance, also responsible for the wonderful Solar eclipses we are able to see.

FULL DESCRIPTION

A pinhole camera can be used to project images from a variety of light sources. When used to project an image of the Sun or the Moon, you can determine the diameter of the source. The image of the light passing through the hole falls on the projection paper at the other end of the pinhole camera box. Using the image of the Sun formed here, we can infer the true diameter of the Sun.

Preparatory activity

First, examine the behavior of a simple pinhole camera [Fig 2]: make a small pinhole in a piece of paper, take another piece of paper for projecting the image (or simply project on the floor), and head outside. Face the pinhole toward the Sun, and examine the projected image on the other piece of paper. Change the distance between the pinhole and the paper, and observe the changes in the image.

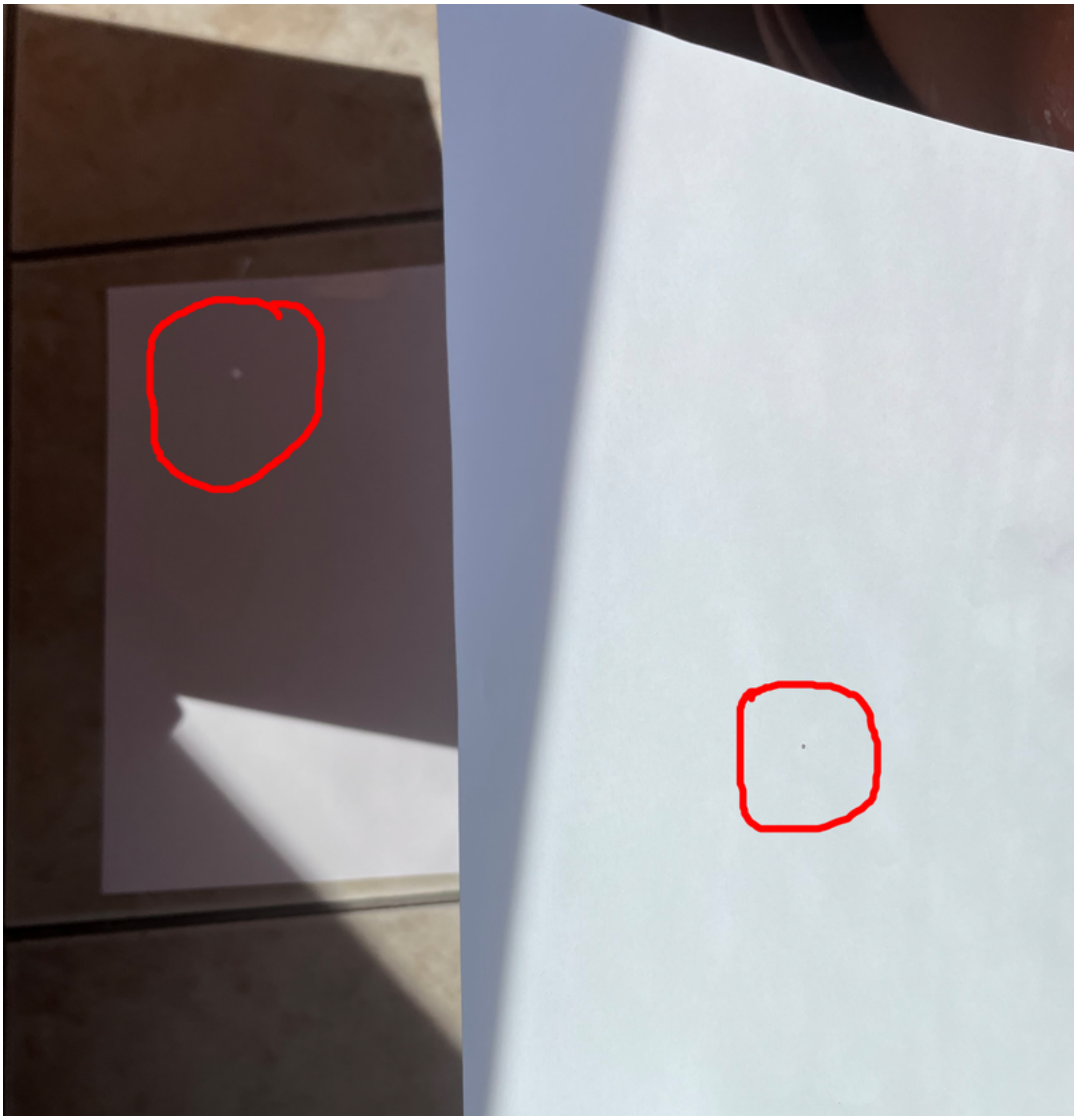


Image: Preparatory Activity: Examine the behavior of a simple pinhole camera

ATTENTION!
Having smaller and defined edged holes as pinholes produces sharper images as they work as a diaphragm.
Also, notice that changing the shape of the pinhole does not affect the image shape we see because the light rays passing through the pinhole are traveling straight forming an inverse image of the same source. The image is NOT the shadow of the hole.

Making the Pinhole Camera

- The pinhole camera will be a rectangular or cylindrical prism box with 15 cm wide on each side. Mark the cardboards every 15 cm. Make light cuts with your utility knife (or use the side of the table or a ruler) to make folding easier.
- Fold all three cardboards and attach them end to end. (If you fold the edges of the cardboard in the middle (blue) to 15.3 cm, the other cardboards

(yellow and pink) will fit inside easily.) Adjust the length of our cardboards to be 100 cm totally. You can also try this application as 200 cm, 300 cm.

Image: Making the Pinhole Camera:cut!

Image: Making the Pinhole Camera:fold!

- Cover one end of your pinhole camera box with a baking sheet (wax paper) as a screen. Optionally, you can also make a visor for this part.
- On the other end of the box, place a piece of aluminum foil or the cardboard over the opening and tape it in place at the edges.
- Using a pin or a needle puncture the foil or cardboard to produce a small hole at the center. You now have a pinhole camera.

Image: Making the Pinhole Camera: pin it!

ATTENTION!
If the tube of the camera is longer, it will be easier to use the pinhole camera to measure the Sun! Choose 100cm or 200cm to make things easier.

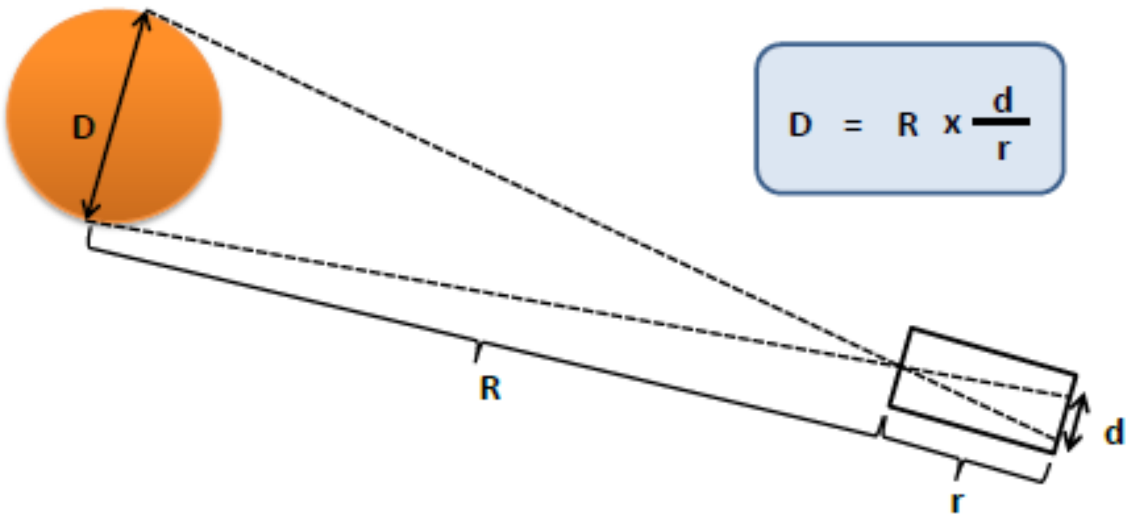
Measuring the Size of the Sun

- Hold the pinhole camera so that the light from the Sun passes through the hole and falls on the wax paper on the other end. You can also use a semi transparent paper and put a grid to find the size of the image of the Sun in the paper.
- Using your ruler or a polygon to measure:

– The diameter of the image of the Sun on the wax paper is **d =…**

– The distance from the pinhole to the wax paper is **r = … (it is better to adjust to 100 cm or 200 cm, ..)**

- You can calculate the diameter of the Sun using the following formula:



where
D= Diameter of the Sun (to be calculated),
R= Distance from the Sun (provided),

d= Diameter of the Sun’s Image (to be measured),
r= Distance of Pinhole to Screen paper (to be defined when building the pinhole camera).

The students can be provided with the distance from Earth to the Sun (R= 149580000 km) and asked to calculate D.

ATTENTION! In alternative students can calculate D using the speed of light (300000 km/s) and the time taken by light to travel from Sun to Earth (8.31 min).

Other suggested activities

- Try making small pinholes with different shapes to understand how they affect the image. For example, use triangle pins or nails to make the hole. Using an arrowhead- shaped diaphragm you can observe that the image of the arrow is inverse. Another way to tackle this: look at the image of the Sun through the leaves in an outdoor environment
- Use the pinhole camera to look out for other objects outside like a tree to find out if the image is reversed right to left or upside down. Show why the image of the tree, as viewed through a pinhole camera, would get smaller as the camera is moved away from the object.
- Try to check if you can see sunspots using the camera.
- Make a room-size pinhole camera covering the windows with black cardboard and making a hole in the middle, use the board or the sidewall as a screen.
- You can use the same procedure to measure the diameter of the Moon. You’ll need to pick a night with a full (or near full) moon. Note: The distance to the Moon is approximately 384,000 kilometers. Compare the size of the Sun and Moon.
- Of course, you can also safely watch an eclipse with your pinhole camera!

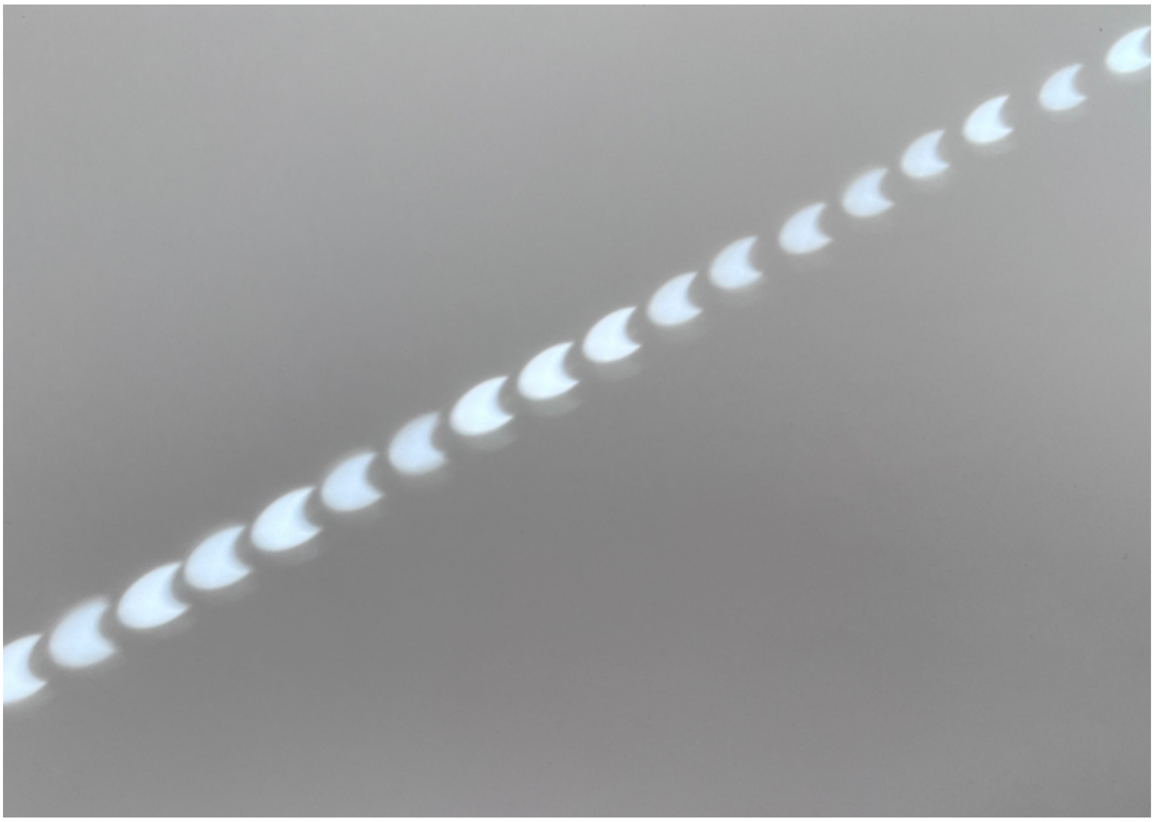


Image: Observing partial solar eclipse on Oct.25, 2022.

EVALUATION

A possible evaluation tool is a class discussion. Here we provide a series of guiding questions for a class discussion:

- Whose pinhole camera worked really well? Why? How does the size of the pinhole affect the brightness of the image on the wax paper? (Answer: The bigger the hole, the brighter the image.)
- How does the size of the pinhole affect the sharpness of the image? (Answer: The bigger the pinhole, the blurrier the image.) How many times larger is the Sun than the Moon? Why if the Sun is so much larger, doesn't it appear larger in the sky?
- Does the shape of the pinhole affect the image? (Answer: no, we always see a circular image. Try making small pinholes with different shapes)
- Where can you use your pinhole camera?

If the activity is proposed in higher grades, also a questionnaire can be used for evaluation. Possible questionnaire for higher grades:

- Question: What is the distance between the Earth and the Sun in kilometers? (R=?) Answer: 8.31 X 60 = 498.6 seconds ; 498.6 X 300000km = 149580000km
- Question: What is the diameter of the Sun in kilometers? (D=?) Answer: If we make the height of our box 200 cm, we will measure 1.86 cm in diameter of the image of the Sun. D = 149580000 X (1.86 x 10-5/ 200 x 10-5) = 149580000 X 0.0093 = 1391094 km
- Question: How many Earth diameters completes one Sun diameter? (D/E =?) Answer: D/E = 1391094km / 12742km = 109 times.
- Question: what is the most accurate measurement? Answer: find the average and error.

CURRICULUM

This activity was developed to be used in a science class at primary or lower secondary school. It can also be used as a practical exercise with older students. It could be used to introduce some concepts in science or physics (Sun, Moon, Solar System, light), geometry (proportions, similar triangles), maths (measurements, histograms, averages, errors, outliers), technology (scientific instruments), history (history of scientific instruments and observations), art (tube decoration) classes.

ADDITIONAL INFORMATION

For more information about the STEAM-Med co-design project : Read this Link

This activity is available in other languages: Link (to be provided soon).

CITATION

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